

THE HISTORY AND FUTURE OF THE UNIVERSE

The Big Bang and Expanding Universe

Space is expanding from an initial moment called the Big Bang. As it expands, the universe becomes less dense and cools. All distant galaxies are moving apart from each other and away from us. On large scales, the universe looks the same in all directions and in all parts of space. There is no center. Our current understanding of the early universe is called the Big Bang model. We are continuing to learn from astronomical observations and from accelerator-based experiments.

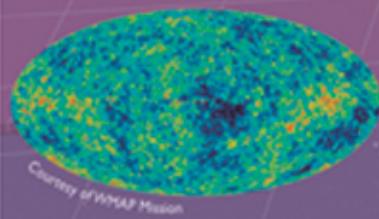
History of the Universe

Cosmology and Relics of History

Cosmology is the study of the universe as a whole. As in archaeology, cosmology finds clues to the past in relics. We can look back in time by looking out in space. Since light travels at a finite speed c , the time t we are looking back is $t = d/c$, where d is the distance. The laws of nature discovered on Earth are applied to the early universe and tested by observing relics.

A Relic from the Early Universe

The Cosmic Microwave Background (CMB) is a universal bath of lightwaves (photons) from the hot, dense, early universe. To one part in 100,000, the CMB is the same no matter where you look. The remaining tiny variations in the density of mass-energy (shown in figure) are seeds that later form galaxies and larger cosmic structures.



This is an image of the universe from the time when atoms first formed. It is a map of the entire sky showing CMB light with the uniform part subtracted.

Age of the Universe

Studying the cosmic microwave background, the expansion of the universe, and the life cycles of stars leads to a marvelous agreement that the age of the universe is about 14 billion years (14×10^9 years).

Four major eras in the expansion history:

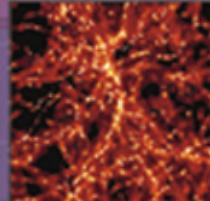
Era 1 – Acceleration: Inflation Speeds Expansion

Observations seem to imply that the very early universe underwent an extremely rapid, accelerating expansion, called inflation. In a tiny fraction of a second, inflation expanded each part of space by a factor of at least 10^{26} . Before inflation, the portion of the universe visible to us today was a smooth patch much smaller than a proton. As inflation ended, the visible universe had grown (very approximately) to the size of a ball.

Eras 2–3 – Deceleration: Expansion Slows and Structure Forms

After inflation, the universe was a soup of fundamental particles, called a quark-gluon plasma. Photons and fast moving particles, generically called radiation, gradually lost energy (cooled) as the universe expanded (the energy went into the expansion). Eventually, slow-moving matter became dominant over radiation. Over time, larger and larger structures grew, from galaxies to clusters of galaxies to superclusters.

Simulation of matter distribution in the early universe that eventually yielded galaxies and clusters of galaxies.



Era 4 – Acceleration: Dark Energy Speeds Expansion

Astronomers had assumed that the current universe is dominated by matter, which would cause deceleration and might even reverse the expansion. So it was a great surprise in 1998 when observations showed that the expansion of the universe is now accelerating (see the "Accelerating Universe" plot). This implies the existence of a bizarre new form of energy, referred to as dark energy.

Four eras and eight major stages

The Big Bang occurred everywhere in the universe and followed through time. The expansion of the universe is divided into four major eras and eight major stages.

Time

10^{-44} s Unknown era

10^{-43} s

Inflation

(sometime between 10^{-43} and 10^{-12} s)

10^{-12} s

10^{-4} s

Nucleons form

10^2 s

Nuclei form

$4 \times 10^5 \text{ yr}$

Atoms form

$3 \times 10^8 \text{ yr}$

First Stars and Galaxies form

$14 \times 10^9 \text{ yr}$

Today

ERA 1

ERA 2

ERA 3

ERA 4

Our Cosmic Neighborhood



Learn more at UniverseAdventure.org and at CPEPweb.org